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**Reithmaier et al.**

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(54) **COST EFFECTIVE LOW PIN/BALL COUNT LEVEL-SHIFTER FOR LCD BIAS APPLICATIONS SUPPORTING CHARGE SHARING OF GATE LINES WITH PERFECT WAVEFORM MATCHING**

3/3674; G09G 2330/023; H03L 5/00; H03K 3/00; H03K 17/56; H03K 19/0185  
See application file for complete search history.

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(65) **Prior Publication Data**

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**Related U.S. Application Data**

(57) **ABSTRACT**

(60) Provisional application No. 61/827,464, filed on May 24, 2013.

A level shifter circuit has a plurality of channels for providing signals to a capacitive load and has circuits for sharing charge stored in the capacitive load between the channels. A first pair of channel clock generating circuits are coupled respectively to a first pair of channels. A second pair of channel clock generating circuits are coupled respectively to a second pair of channels. A pair of switches couple the first pair of channels together and the second pair of channels together, respectively, for sharing charge between the channels. A single resistor is coupled in circuit with all of the channels for controlling a slope of charge sharing between channels.

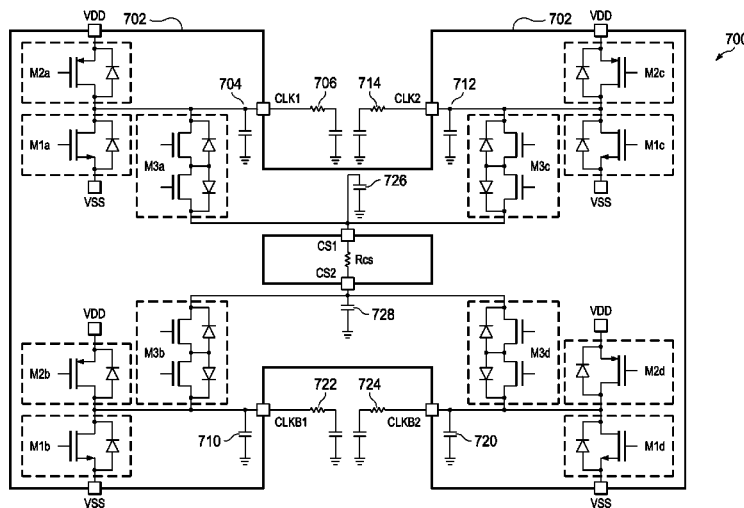
(51) **Int. Cl.**  
**G09G 3/36** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **G09G 3/3659** (2013.01); **G09G 3/3674** (2013.01); **G09G 2310/0289** (2013.01); **G09G 2330/023** (2013.01)

(58) **Field of Classification Search**

CPC G09G 5/00; G09G 5/14; G09G 3/00–3/3696; G09G 2310/0289; G09G 3/3659; G09G

**20 Claims, 8 Drawing Sheets**



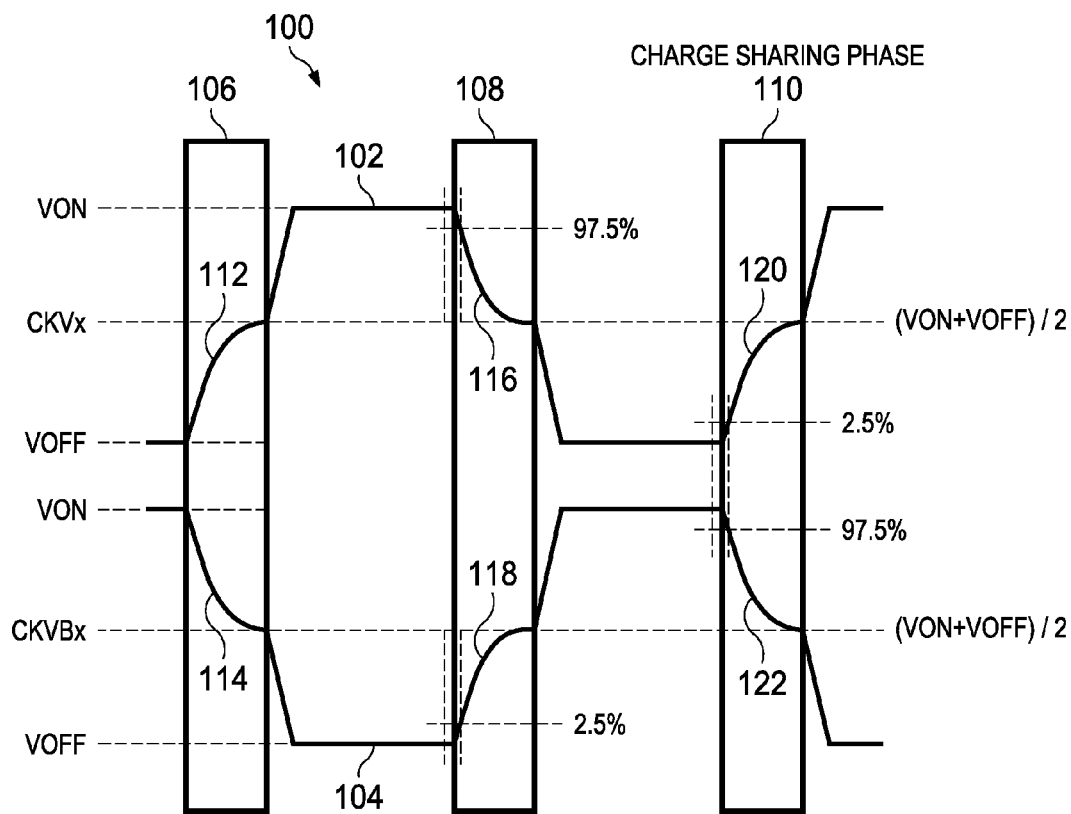


FIG. 1  
(PRIOR ART)

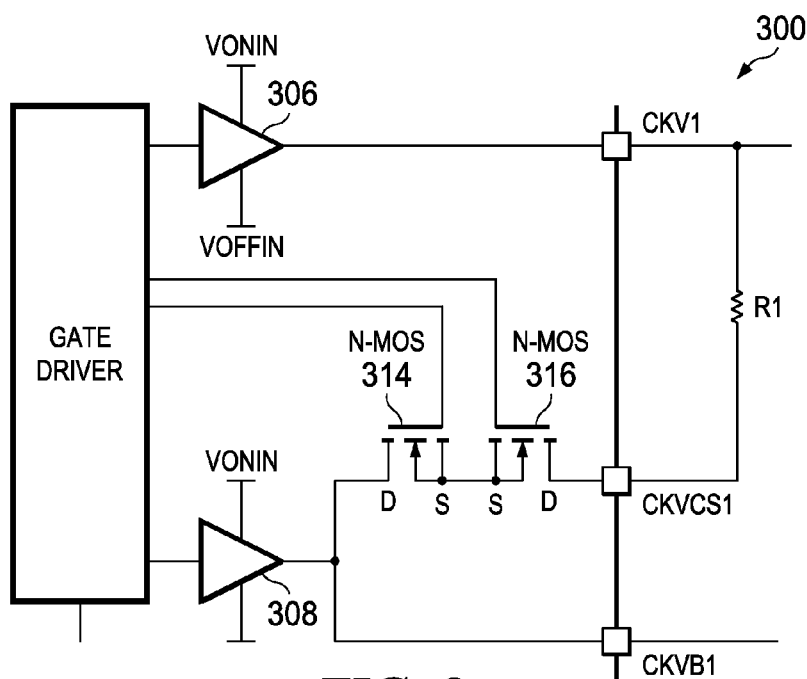


FIG. 3  
(PRIOR ART)

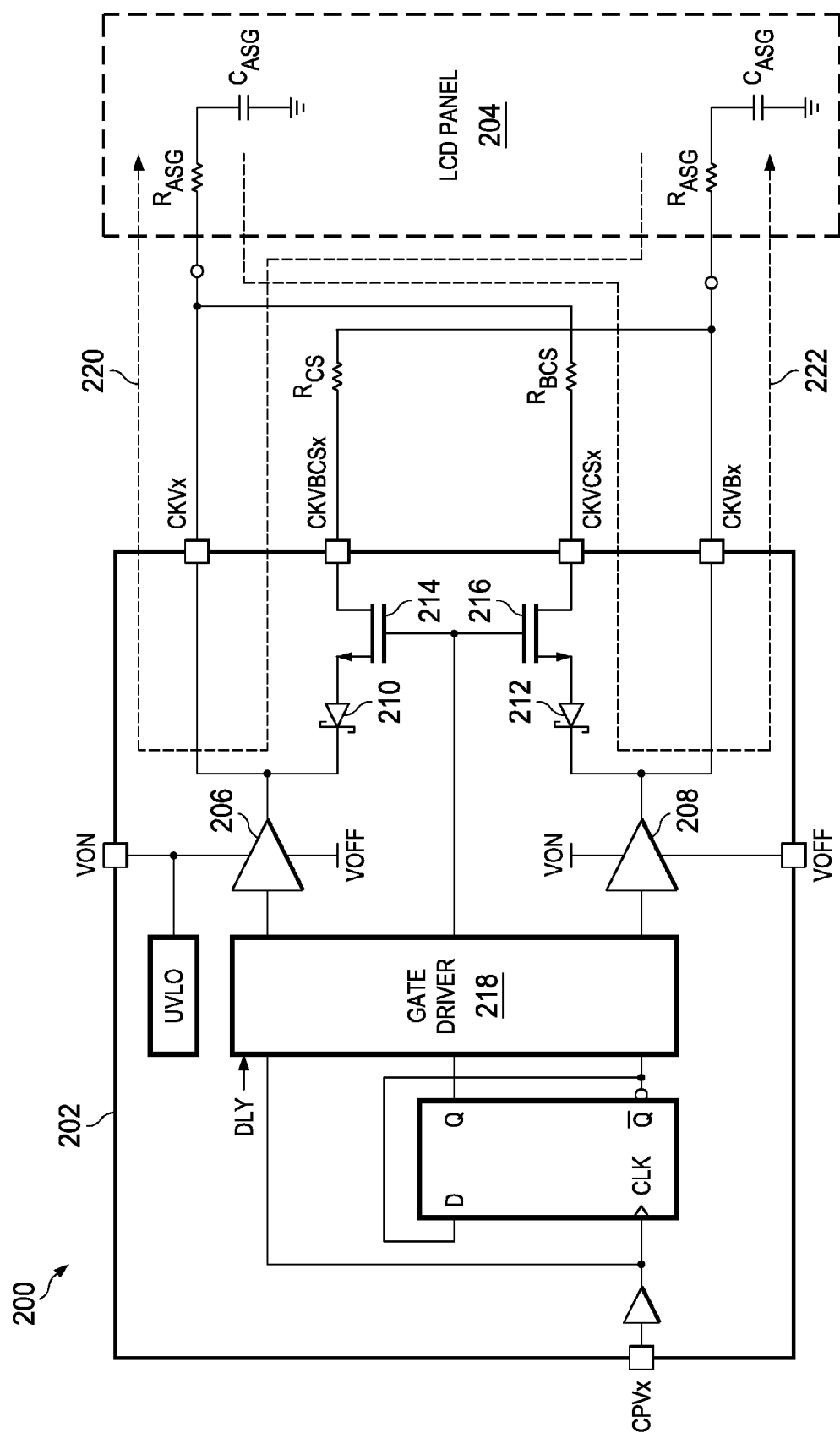
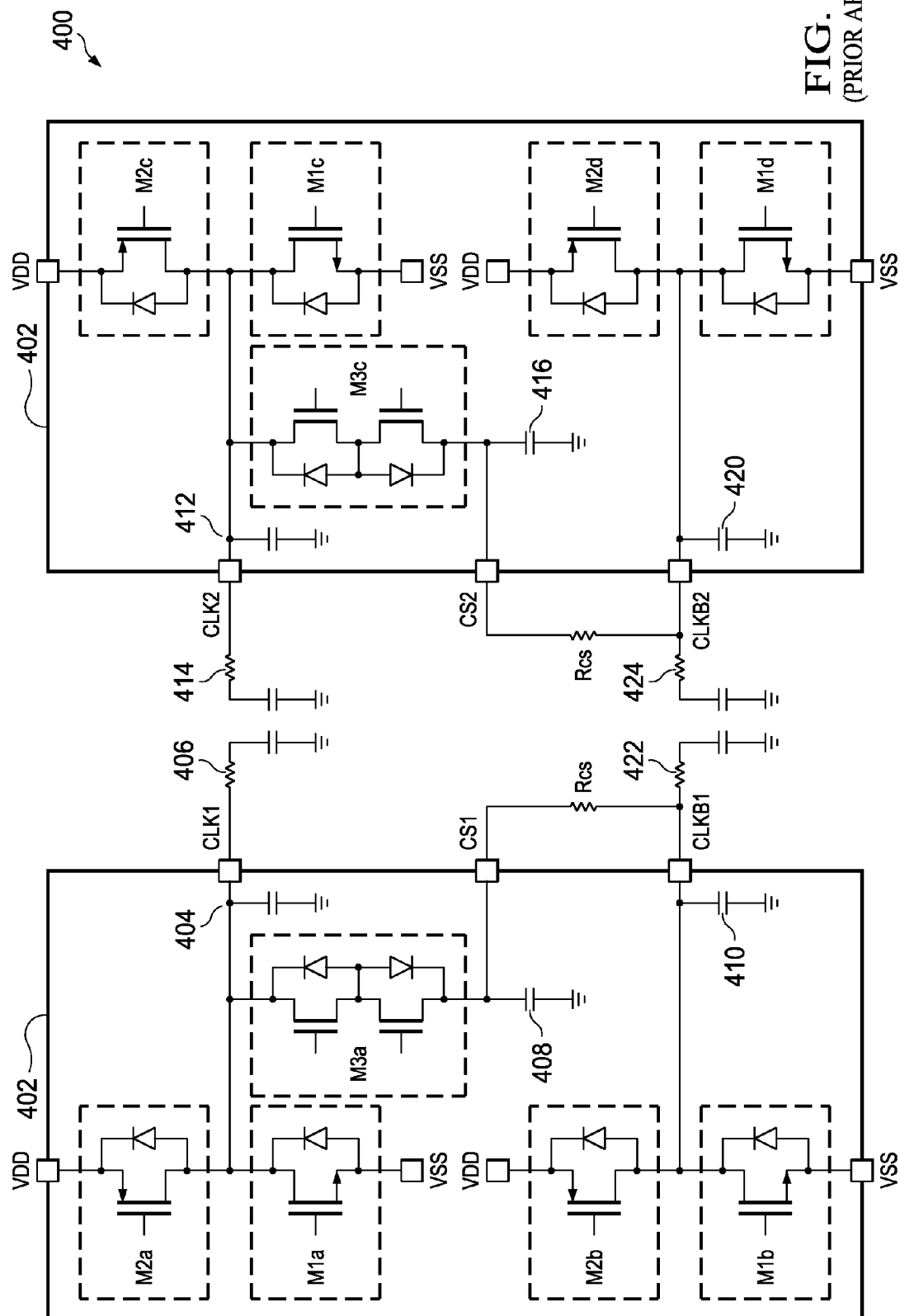
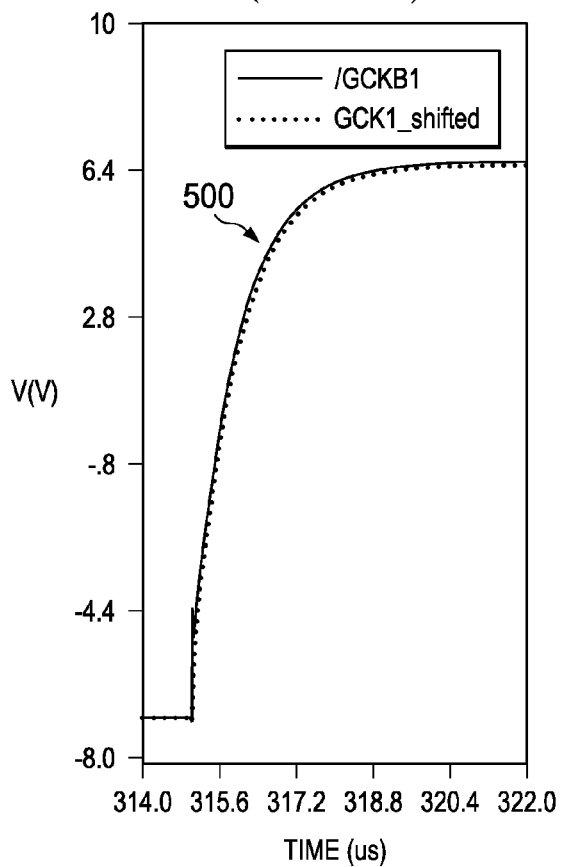


FIG. 2  
(PRIOR ART)

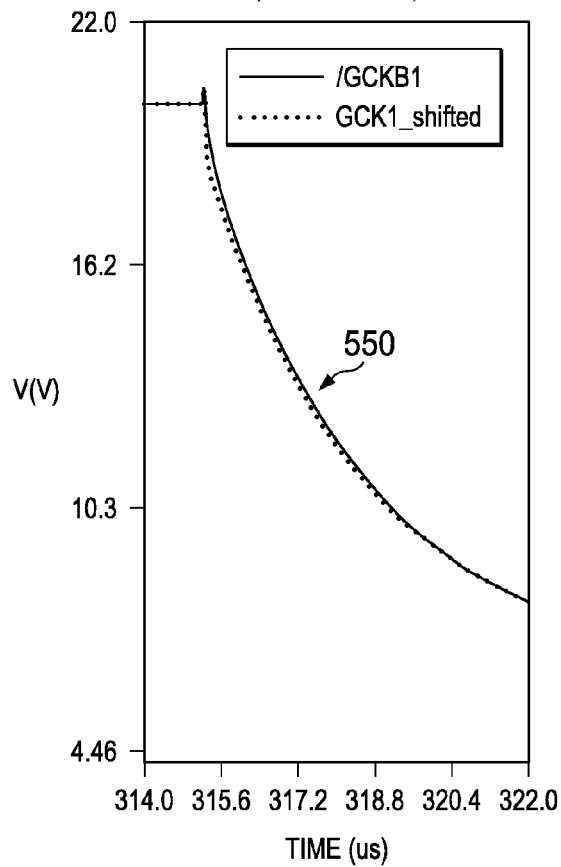


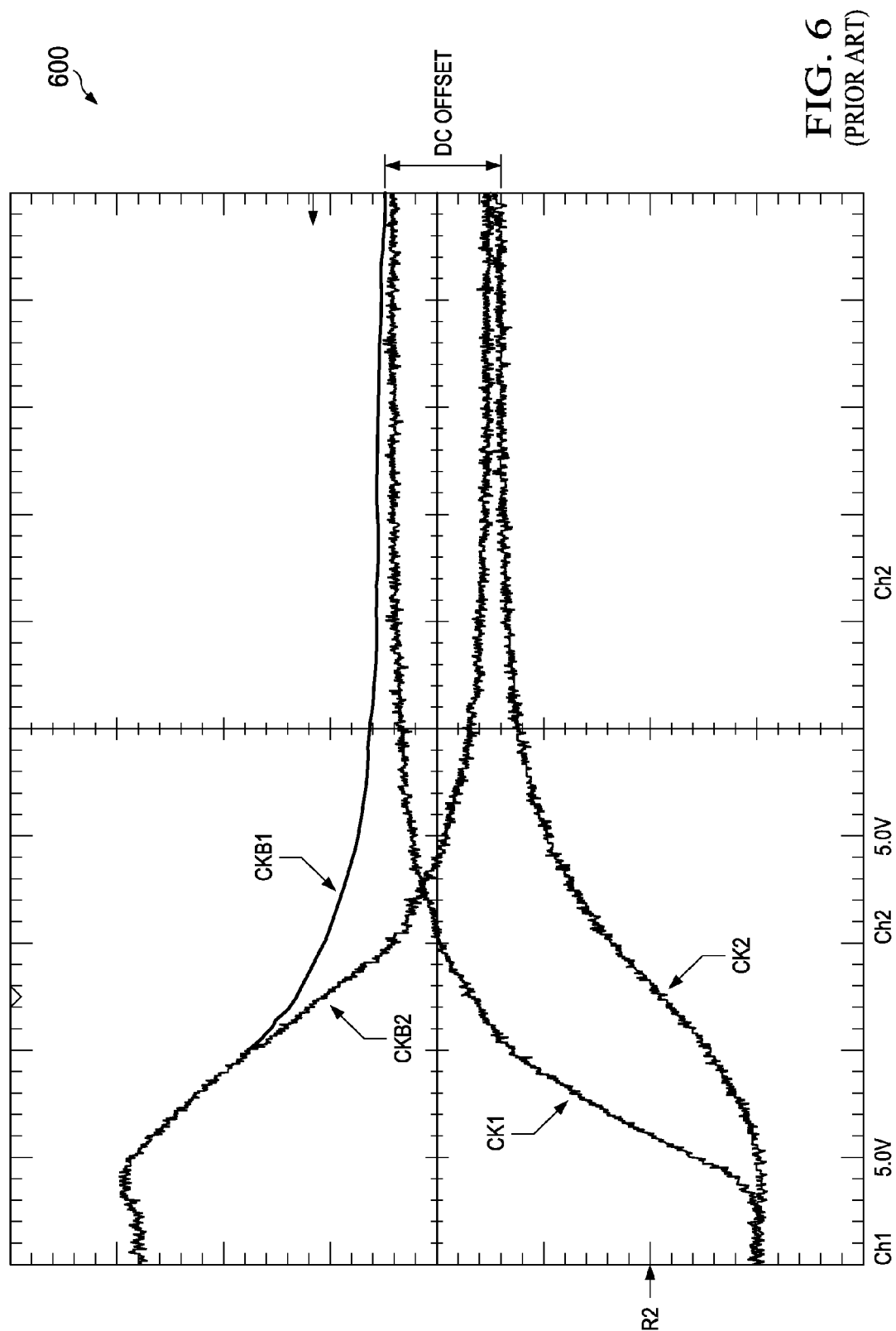
**FIG. 4**  
**(PRIOR ART)**

**FIG. 5A**  
(PRIOR ART)



**FIG. 5B**  
(PRIOR ART)





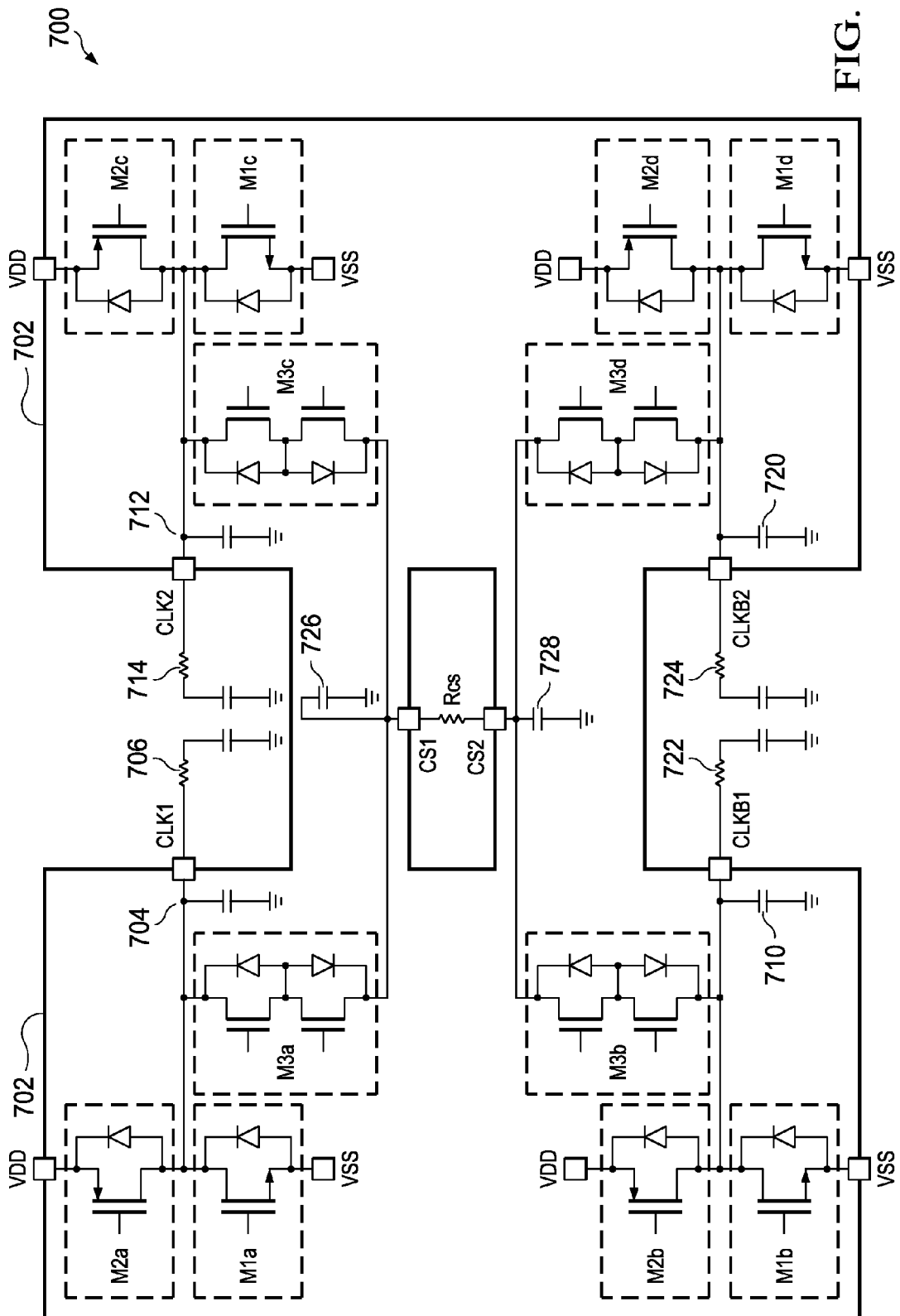


FIG. 7

FIG. 8A

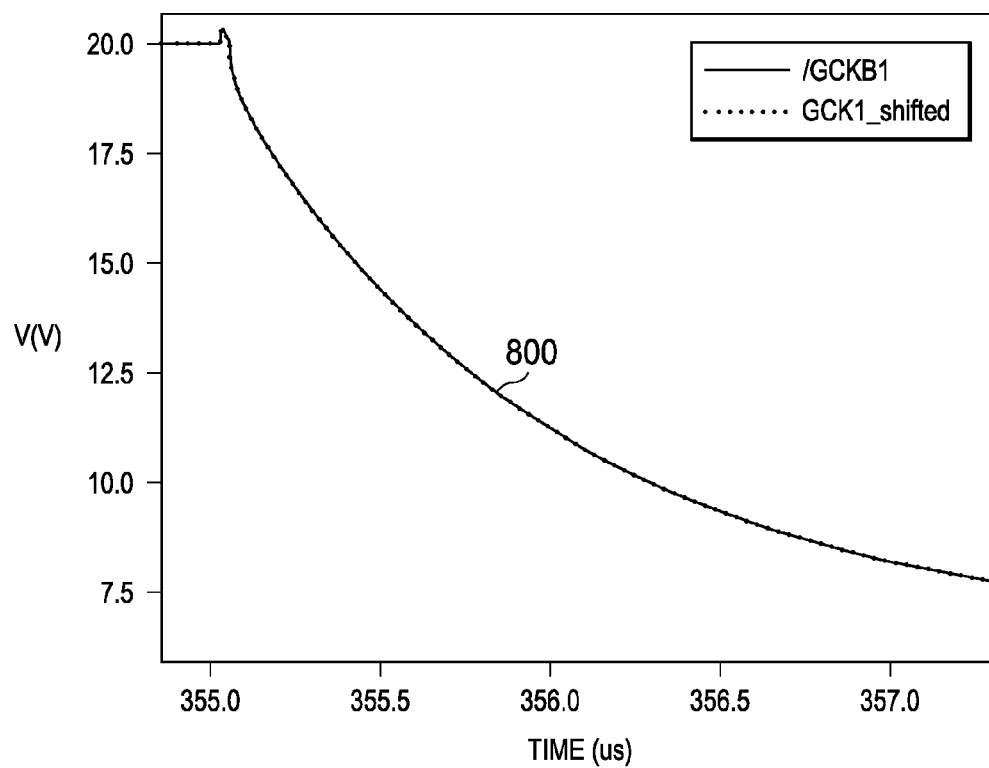
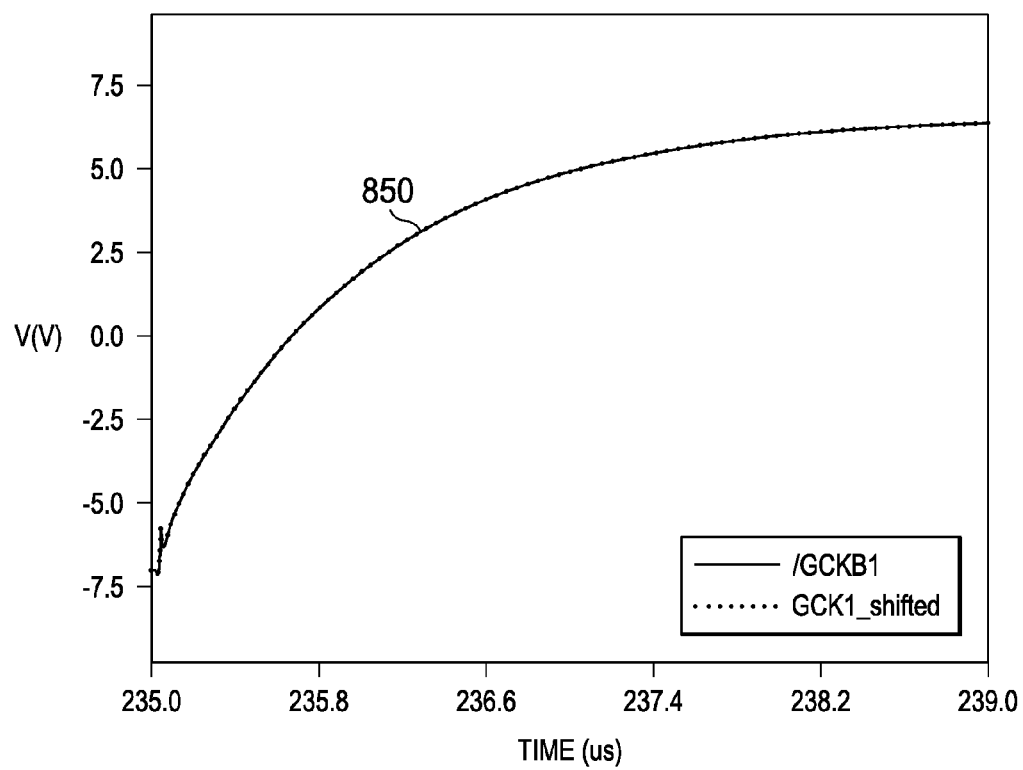


FIG. 8B





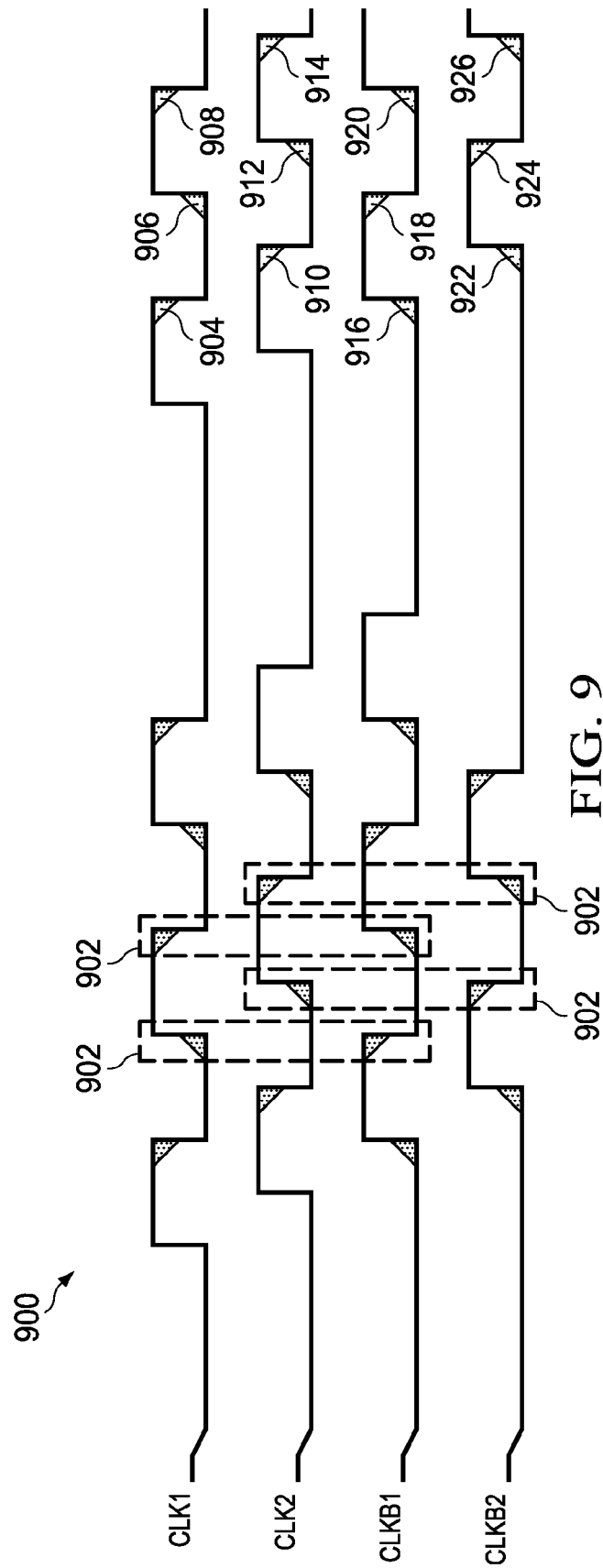


FIG. 9

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# COST EFFECTIVE LOW PIN/BALL COUNT LEVEL-SHIFTER FOR LCD BIAS APPLICATIONS SUPPORTING CHARGE SHARING OF GATE LINES WITH PERFECT WAVEFORM MATCHING

## CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application claims priority from U.S. Provisional Application No. 61/827,464, filed May 24, 2013, which is incorporated herein by reference in its entirety for all purposes.

## FIELD OF THE INVENTION

The invention relates to a level shifter circuit and more specifically to a level shifter circuit for a liquid crystal display (LCD).

## BACKGROUND OF THE INVENTION

Liquid crystal displays (LCDs) are widely used in computer monitors, laptop computers, tablet computers, cellular telephones, video players, cameras, watches and television sets, as well as other devices. LCDs are chosen because they are small in size, light in weight, low in power consumption and able to produce high-resolution images. LCDs are often in the form of display panels having row and column address lines coupled to pattern generator electronics which generate patterns or video on the display. As is well known, the voltage required by the LCD is often much greater than the voltage handling capacity of the pattern generator electronics. Therefore, it is common to utilize a level shifter circuit between the pattern generator electronics and the display to convert a lower voltage signals from the pattern generator electronics to the voltage required to drive the display.

The row lines of the display can be modeled as a capacitor in series with a resistor. As is well known, the power required to charge up the capacitive load is a significant portion of the power required to drive the display. Thus, it is common to share this charge between a first row line and a second row line, which are operated out of phase with each other. This charge sharing phase is illustrated in FIG. 1 generally as 100. The two clock signals 102, 104 are 180° out of phase with each other and share charge during the time periods shown in the rectangles 106, 108 and 110. In rectangle 106 charging can be seen at 112 and the discharging can be seen at 114. In rectangle 108, the discharging can be seen at 116 and charging can be seen at 118. In rectangle 110 charging can be seen at 120 and discharging can be seen at 122.

A prior art LCD system having an LCD panel 204 and a driving circuit 202 is shown in FIG. 2 generally as 200. The driving circuit 202 includes circuitry for performing the charge sharing shown in FIG. 1. In FIG. 2, each of the row lines of the LCD panel 204 is modeled as a resistor  $R_{ASG}$  in series with a capacitor  $C_{ASG}$ . Circuit 202 comprises, inter alia, a gate driver circuit 218 driving buffers 206, 208 and providing a signal to charge transfer transistors 214, 216. Diodes 210, 212 prevent reverse current flow. When activated, transistor 214 allows current to flow as shown by dotted lines 220, and transistor 216, when activated, allows current to flow as shown by dotted lines 222. Resistors  $R_{CS}$  and our  $R_{BCS}$  control the slope of the charge/discharge in order to reduce visual effects on the LCD panel. One disadvantage of the circuit is that it requires two pins or balls for each channel.

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FIG. 3 shows a prior art circuit 300 which utilizes transistors 314, 316 in place of the diodes 210, 212 shown in FIG. 2, and which allows the utilization of a single resistor R1 in place of the two resistors  $R_{CS}$  and  $R_{BCS}$  shown in the circuit of FIG. 2.

FIG. 4 shows a prior art circuit for driving four row lines or channels generally as 400. For ease of illustration, the integrated circuit 402 is shown divided into a left side and right side circuit, but those skilled in the art will recognize that only a single integrated circuit is required. This circuit utilizes the single resistor charge sharing scheme shown in FIG. 3. The row lines 406, 414, 422, 424 are each modeled as a resistor in series with a capacitor to ground. The driver circuit for row 406 comprises a push-pull circuit consisting of transistors M1a and M2a coupled between VDD and VSS and having an output coupled to channel CLK1. Transistors M3a correspond to the transistors 314, 316 shown in FIG. 3, which replace the diodes 210, 212 in FIG. 2. Parasitic capacitor 404 is present at pin CLK1 and parasitic capacitor 408 is present at pin CS1. These parasitic capacitors are a result of the electrostatic discharge (ESD) circuits at those pins as well as the parasitic capacitances of the transistors M3a.

Similarly, the driver circuit for row 422 comprises a push-pull circuit consisting of transistors M1b and M2b coupled between VDD and VSS and having an output coupled to channel CLKB1. Parasitic capacitance 410 is present on pin CLKB1. The driver circuit for row 414 comprises a push-pull circuit consisting of transistors M1c and M2c coupled between VDD and VSS and having an output coupled to channel CLK2. Transistors M3c correspond to the transistors 314, 316 shown in FIG. 3, which replace the diodes 210, 212 in FIG. 2. Parasitic capacitor 412 is present at pin CLK2 and parasitic capacitor 416 is present at pin CS2. These parasitic capacitors are as a result of the ESD circuits at those pins as well as the parasitic capacitances of the transistors M3c. The driver circuit for row 424 comprises a push-pull circuit consisting of transistors M1d and M2d coupled between VDD and VSS and having an output coupled to channel CLKB2. Parasitic capacitor 420 is present at pin CLKB2.

Although this circuit allows the resistors  $R_{CS}$  to be shared between a channel pair [RS1] and thus reduces the pin count, it creates a new problem for the latest LCDs and fails to solve an older problem. A problem is created for the latest LCDs in that driving channel 406, for example, includes the effects of the parasitic capacitance 408, whereas driving line 422 does not include this parasitic capacitance. A similar situation exists when sharing charge between the two row lines. Thus, the slope of the charging (rising) and discharging (falling) waveforms will be different, as illustrated in FIG. 5A showing the slope of the charging waveform and FIG. 5B showing the slope of the discharging waveform. This difference in slope creates a DC offset as shown in FIG. 6, generally as 600. The DC offset is shown at the right side of the waveform. This can create objectionable visual effects on the latest LCDs. Furthermore, the older problem that is not solved, is the fact that although resistors are shared between two channels, different resistors, normally discrete components, are utilized for each pair of channels. There will be a difference in resistance between these shared resistors, which can give rise to differences in the slope during charge sharing, which may result in objectionable visual effects on the display.

Thus, there is a need for improved level shifter for LCD applications.

## SUMMARY OF THE INVENTION

It is a general object of the invention to provide a level shifter circuit where a single resistor can be shared between a plurality of channels.

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This and other features and objects of the invention can be proved by a aspect of the invention which includes a level shifter for a liquid crystal display (LCD) comprising first row line control circuit to control a first row line of the LCD. A second row line control circuit controls a second row line of the LCD. A third row line control circuit controls a third row line of the LCD. A fourth row line control circuit controls a fourth row line of the LCD. A first switch is coupled to the first and the second row line control circuits for sharing charge stored on the first row line with the second row line. A second switch is coupled to the third row line control circuit and the fourth row line control circuit for sharing charge stored on the third row line with the fourth row line. A single resistor is coupled between the first switch and the second row line control circuit and coupled between the second switch and the fourth row line control circuit, wherein the slope of charge and discharge voltages on the row lines are substantially identical.

Another aspect of the invention comprises a liquid crystal display (LCD) comprising: an LCD panel having pixels arranged in rows and columns. A level shifter circuit is coupled to at least four row lines of the LCD panel, the level shifter shifting the voltage level of signals generated by a display pattern generator circuit to control the row lines of the LCD panel. A plurality of switches are each coupled between a pair of row lines for sharing charge stored on one row line with a second row line through a single resistor.

A further aspect of the invention is provided by a level shifter circuit having a plurality of channels for providing signals to a capacitive load and having circuits for sharing charge stored in the capacitive load between the channels. A first pair of channel clock generating circuits are coupled respectively to a first pair of channels. A second pair of channel clock generating circuits are coupled respectively to a second pair of channels. A pair of switches couples the first pair of channels together and the second pair of channels together, respectively, for sharing charge between the channels. A single resistor coupled in circuit with all of the channels for controlling a slope of charge sharing between channels.

#### BRIEF DESCRIPTION OF DRAWINGS

Further aspects of the invention will appear from the appending claims and from the following detailed description given with reference to the appending drawings.

FIG. 1 is illustration of charge sharing between channels of an LCD;

FIG. 2 is a schematic of a prior art circuit for performing charge sharing between channels;

FIG. 3 is a schematic of a prior art circuit for charge sharing between channels using a shared resistor;

FIG. 4 is a schematic of a prior art circuit showing charge sharing between four channels utilizing two shared resistors;

FIG. 5A is an illustration of a rising (charging) signal;

FIG. 5B is illustration of a falling (discharging) signal for charge sharing between channels;

FIG. 6 shows a DC offset generated by the differences in slope between the signals of FIGS. 5A and 5B;

FIG. 7 is a schematic diagram of a level shifter circuit of the present invention having improved charge sharing characteristics;

FIG. 8A shows the falling (discharging) signal of a pair of channels;

FIG. 8B shows a rising (charging) signal of a pair of channels for the circuit of FIG. 7; and

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FIG. 9 shows the drive signals for four channels of an LCD having the charge sharing characteristics of the circuit shown in FIG. 7.

#### DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

Referring now to FIG. 7, an embodiment of the present invention is shown generally as **700**. The circuit **700** includes an integrated circuit portion **702**. It is to be understood that the "H" configuration shown for the integrated circuit **702** is for clarity of illustration only. Those skilled in the art will recognize that this circuit can be implemented in other shapes and sizes appropriate for an integrated circuit without departing from the present invention. The integrated circuit **702** drives four rows or channels **706**, **722**, **714** and **724** of LCD. Each of the rows or channels is modeled as a resistor in series with a capacitor (unlabeled in FIG. 7).

Row **706** is driven by a push-pull circuit comprising transistor **M2a** in series with transistor **M1a** and coupled between VDD and VSS. The output of the push-pull driver is taken between the two transistors and coupled to pin **CLK1** which is coupled to the row **706**. A parasitic capacitance **704** is present at pin **CLK1**. Also coupled to the pin **CLK1** and the output of the push-pull driver circuit **M1a** and **M2a** are transistors **M3a** which correspond to the same transistors illustrated in FIG. 4. The other terminal of the transistors **M3a** is connected to pin **CS1** as shown in FIG. 4. A parasitic capacitance **726** is present at pin **CS1** similar to the parasitic capacitance **408** shown in FIG. 4.

A second row or channel **CLKB 1** is driven by a push-pull driver circuit comprising transistor **M2b** in series with transistor **M1b** and coupled between VDD and VSS. The output of the push-pull driver is taken between the two transistors and coupled to pin **CLKB1** which is coupled to the row **722**. A parasitic capacitance **710** is present at pin **CLKB1**. Unlike the circuit shown in FIG. 4, the output of the push-pull driver **M1b**, **M2b** and the pin **CLKB1**, is coupled via transistors **M3b** to the pin **CS2**. The transistors **M3b** are similar to the transistors **M3a** discussed above. A parasitic capacitance **728** is present at pin **CS2**.

Similarly, to the drive for row **706**, row **714** is driven by a push-pull circuit comprising transistor **M2c** in series with transistor **M1c** and coupled between VDD and VSS. The output of the push-pull driver is taken between the two transistors and coupled to pin **CLK1** which is coupled to the row **706**. A parasitic capacitance **712** is present at pin **CLK2**. Also coupled to the pin **CLK2** and the output of the push-pull driver circuit **M1c** and **M2c** are transistors **M3c** which correspond to the same transistors illustrated in FIG. 4. Unlike the circuit shown in FIG. 4, the other terminal of the transistors **M3c** is connected to pin **CS1**. As discussed above, a parasitic capacitance **726** is present at pin **CS1**.

Similarly to the drive for row **722**, a third row or channel **CLKB2** is driven by a push-pull driver circuit comprising transistor **M2d** in series with transistor **M1d** and coupled between VDD and VSS. The output of the push-pull driver is taken between the two transistors and coupled to pin **CLKB2** which is coupled to the row **724**. A parasitic capacitance **720** is present at pin **CLKB2**. Unlike the circuit shown in FIG. 4, the output of the push-pull driver **M1d**, **M2d** and the pin **CLKB2**, are coupled via transistors **M3d** to the pin **CS2**. The transistors **M3d** are similar to the transistors **M3a** discussed above. As discussed above, a parasitic capacitance **728** is present at pin **CS2**.

A single resistor  $R_{CS}$  is coupled between the pins **CS1** and **CS2** and serves as the resistance to control the slope of the

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charge and discharge of the capacitances for the row lines for all four rows or channels illustrated in FIG. 7. The resistor  $R_{CS}$  may be the only component in the system illustrated in FIG. 7 to be external to the integrated circuit 702. Thus, criticality of this component has been removed.

In operation, each of the rows or channels is operated from a different phase of a clock signal, so that no two drivers are operating at the same time. During one phase, charge may be transferred from the capacitor in row 706 via pin CLK1, through transistors M3a, through pin CS1, resistor  $R_{CS}$ , pin CS2, through transistors M3b, through-pin CLKB1 into the capacitor for row 722, for example. In a second phase, charge flowing from the capacitor in row 722 would follow the opposite path for charging the capacitor in row 706. In a third phase, charge flowing from the capacitor in row 714 would flow through pin CLK2, through transistors M3c, pin CS1, resistor  $R_{CS}$ , pin CS2, through transistors M3d, pin CLKB2, into the capacitor for row 724, for example. In a fourth phase, charge flowing from the capacitor in row 724 would follow the opposite path for charging the capacitor in row 714. Other patterns of the charge/discharge cycle can be used as long as only one channel is active at a time.

It should be noted that the charge and discharge paths between the rows are identical for each pair of row drivers. It should further be noted that on an integrated circuit, the values of the parasitic capacitances at the various pins will be substantially the same, thus assuring that the charge and discharge paths between all of the rows is essentially the same. This is seen in FIG. 8A which shows the discharge waveform of two channels, phase shifted so that they are in time alignment. This waveform 800 appears to be a single waveform, whereas it is actually the waveform for two channels superimposed on each other. Thus a substantial identity of the two discharge cycles can be seen. Similarly, the waveform 850 in FIG. 8B shows the charging waveform of two channels with the waveforms time shifted so that they are superimposed upon each other.

Again, the waveform 850 appears to be a single waveform, whereas it is actually two identical waveforms superimposed upon each other. Thus, identity of the charge and discharge waveform can be seen, and, the visual effects produced by the circuit shown in FIG. 4 have been eliminated or very substantially reduced.

Furthermore, all of the charge/discharge paths utilize the same resistor  $R_{CS}$ . Thus, the time constant for all the channels will be substantially identical. Therefore, the criticality of this component selection has been removed. Furthermore, the same resistor can be utilized for additional pairs of channels saving pins or solder bumps on the integrated circuit, which will reduce the cost of the integrated circuit. Although a circuit utilizing four channels is shown in FIG. 7, the circuit can be expanded to other configurations by adding pairs of channels, but only a single resistor is needed. Thus, the circuit can comprise 6, 8, 10, etc. channels utilizing a single resistor  $R_{CS}$ .

FIG. 9 shows the operation of the driver for the LCD. The signals CLK, CLK2, CLKB1 and CLKB2 correspond to the signals at the pins having the same label and FIG. 7. As can be seen, each of the signals are 90° out of phase with the preceding signal. Thus, the signal CLK2 lags the signal CLK1 by 90°. The signal CLKB1 lags the signal CLK2 by 90° and the signal CLKB2 lags the signal CLKB1 by 90°. Charge sharing is shown in the rectangles 902. The shaded areas represent the portions of the signal where charge sharing takes place. In the signals on the right side of the figure, charge sharing can be seen at 904, 906, 908, 910, 912, 914, 916, 918, 920, 922, 924 and 926.

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Although the invention has been described in detail, it should be understood that various changes, substitutions and alterations can be made thereto without departing from the spirit and scope of the invention as defined by the appended claims.

The invention claimed is:

1. A level shifter for a liquid crystal display (LCD) comprising:

- a first row line control circuit to control a first row line of the LCD;
- a second row line control circuit to control a second row line of the LCD;
- a third row line control circuit to control a third row line of the LCD;
- a fourth row line control circuit to control a fourth row line of the LCD;
- a first switch coupled to the first and the second row line control circuits for sharing charge stored on the first row line with the second row line;
- a second switch coupled to the third row line control circuit and the fourth row line control circuit for sharing charge stored on the third row line with the fourth row line; and
- a single resistor coupled between the first switch and the second row line control circuit and the single resistor coupled between the second switch and the fourth row line control circuit, wherein a slope of charge and discharge voltages on the row lines are substantially identical.

2. The level shifter of claim 1 wherein the four row line control circuits controlling the four row lines of the LCD are substantially identical.

3. The level shifter of claim 2 wherein all of the row line control circuits and a switch for each pair of row lines are on an integrated circuit and wherein the only component not integrated is the single resistor.

4. The level shifter of claim 1 wherein the row lines of the LCD are arranged in pairs to share charge stored on the row lines of the display and with all the row lines share charge utilizing the single resistor.

5. The level shifter of claim 4 wherein a number of row lines of the LCD is expanded to 6, 8, or 10.

6. The level shifter of claim 5 wherein all of the row line control circuits and a switch for each pair of row lines are on an integrated circuit and wherein the only component not integrated is the single resistor.

7. The level shifter of claim 4 wherein all of the row line control circuits and a switch for each pair of row lines are on an integrated circuit and wherein the only component not integrated is the single resistor.

8. A liquid crystal display (LCD) comprising:

- an LCD panel having pixels arranged in rows and columns;
- a level shifter circuit coupled to at least four row lines of the LCD panel, the level shifter shifting a voltage level of signals generated by a display pattern generator circuit to control the row lines of the LCD panel;
- a first pair of switches each coupled between a first pair of row lines for sharing charge stored on a first row line with a second row line and a second pair of switches coupled between a second pair of row lines for sharing charge stored on a third row line with a fourth row line, each charge sharing being through the same resistor.

9. The LCD panel of claim 8 wherein the level shifter circuit comprises four substantially identical row line clock generator circuits.

10. The LCD panel of claim 9 wherein the level shifter circuit is an integrated circuit and wherein the only component not integrated is the resistor.

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11. The LCD panel of claim 8 wherein a number of row lines of the LCD is expanded to 6, 8, or 10.

12. The LCD panel of claim 11 wherein the level shifter circuit is an integrated circuit and wherein the only component not integrated is the resistor.

13. The LCD panel of claim 8 wherein the level shifter circuit is an integrated circuit and wherein the only component not integrated is the resistor.

14. A level shifter circuit having a plurality of channels for providing signals to a capacitive load and having circuits for sharing charge stored in the capacitive load between the channels comprising:

a first pair of channel clock generating circuits coupled respectively to a first pair of channels;

a second pair of channel clock generating circuits coupled respectively to a second pair of channels;

a pair of switches coupling the first pair of channels together and the second pair of channels together, respectively, for sharing charge between the channels; and

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a single resistor coupled between the channels for providing a symmetrical slope for charge and discharge voltages between channels.

15. The level shifter circuit of claim 14 wherein the four channels are substantially identical.

16. The level shifter circuit of claim 15 wherein the channel clock generating circuits and switches on a single integrated circuit and wherein the only component not integrated is the single resistor.

17. The level shifter circuit of claim 15 wherein a number of channels is expanded to 6, 8, or 10.

18. The level shifter circuit of claim 14 wherein the channel clock generating circuits and switches on a single integrated circuit and wherein the only component not integrated is the single resistor.

19. The level shifter circuit of claim 18 wherein a number of channels is expanded to 6, 8, or 10.

20. The level shifter circuit of claim 14 wherein a number of channels is expanded to 6, 8, or 10.

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